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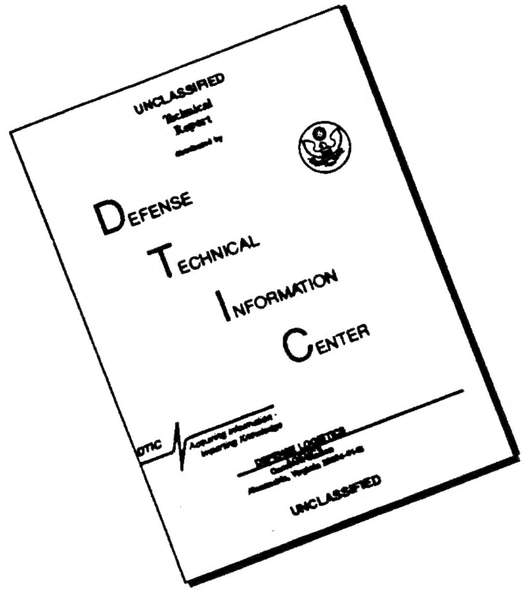

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The effects of fatigue and G-layoff on performance during high-G are mostly unknown for the female population. This research was conducted in the centrifuge Dynamic Environment Simulator (DES). Eight male and eight female active-duty personnel were trained to fly the F-16 simulation while thirty performance measures were recorded. Performance was re-evaluated after 24 hrs. of sleeplessness and after either 2 or 4 weeks of lay-off.

Neither male nor female overall performance was significantly affected by sleep status, although individual tasks showed sensitivity; call-sign reaction time was longer by 33% and missile survival was less likely. Also, perceived effort and physical demand were higher while perceived performance was lower when sleepless. No differences in performance were found in either gender due to lay-off, although some physiologic deconditioning was apparent.

Women commanded and endured the same amount of G load as men, however on average they could not perform the tracking task quite as well. Women also reported more adverse effects of exposure. Nothing was found that suggests that women should not fly high performance aircraft.

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Tamara L Chilette   12 July 96
PI - Signature   Date

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INTRODUCTION

NATURE OF THE PROBLEM

Some ground-based research has investigated the loss of cognitive function in the extreme conditions of G-induced loss of consciousness (G-LOC), however, little is known about pilots' abilities to maintain cognitive performance throughout prolonged conscious exposure in the high G environment. The recent deployment of positive pressure breathing for G (PBG) systems in the US Air Force, as well as the pending deployment of advanced technology full-coverage anti-G suits, is resulting in longer duration high-G exposure [1]. Gz doses of greater than a million G-seconds are being anticipated [2]. There have been only a few experiments concerning crew performance with these advanced suits in the military arena [3, 4, 5] and few have been published in the open literature.

Thirteen females are now flying high performance aircraft in the US Air Force. Eight are currently in training. The effects of sustained acceleration (high-G) on women and their performance in a fighter cockpit are unknown. It has been stated that there are no performance differences between females and males at high G, but only scant data and anecdotal evidence are documented [6].

BACKGROUND

In 1944, the first experiment documenting impairment of cerebral function during exposure to G forces described subjects with confusion and momentary memory loss [7]. Frankenhauser's 1949 report documented increased reaction times to a multiplication task during 2-10 minute exposures to +3 Gz [8]. Canfield et al. in their 1949 investigation of vision under G showed increased reaction times to visual discrimination tasks during +3-5 G exposure for 15 seconds [9]. Chambers and Hitchcock demonstrated increased errors in a memory task during 90 second exposures at +6-7 Gz in 1963 [10]. In 1968 Little, Leverett, and Hartman also observed tracking decrements during accelerations of +5-9 Gz [11]. Piranian showed increased tracking error during exposure to +5 Gz [12]. Frazier et al., and Darwood et al., both in 1990, showed increased error in time and weight estimation tasks, respectively, during long duration centrifuge exposure but only up to +4 Gz [13,14]. Albery et al. used a maze solving task [15] and then later used a dual tracking task [16] and documented a decreased performance with increased G stress over a 60 second period.

In contrast, there are several studies that have shown no significant performance decrement under G. Canfield, Comrey, and Wilson in 1948 found no effect on a memory matching task during exposures up to +5 Gz [17]. Again in 1950, Canfield et al. had consistent performance up to +5 Gz on a visual reaction time task [18]. Creer found no tracking task decrements at any acceleration level up to 6 Gz for 2.5 minutes using a heavily damped control task. Between +6 and +9 Gz, performance dropped rapidly, attributed primarily to the serious visual degradation occurring above +7Gz [19].

Grether reviewed the effects of acceleration on performance, and concluded that simple and choice reaction times to visual signals generally increase during increased levels of +Gz. However, these effects tend to diminish or disappear as humans become more accustomed to acceleration environments [20].

The study of cognitive performance during prolonged 3 minute conscious exposure to high G levels has only recently become necessary with the deployment of advanced protective equipment. Some research has investigated the loss of cognitive function in these extreme conditions as related to G-induced loss of consciousness [21,22 ,23, 24] but little is known about the effect on task performance during continuous conscious exposure to high G.

Although women have participated in acceleration studies in the past, their numbers have been few. The effects of fatigue and G-layoff on performance during high-G are largely unknown for the female population. This research project is part of our on-going mission to address high-G performance issues of interest and priority to Air Combat Command which has specifically asked the Armstrong Laboratory to "determine female-specific training needs" [25].

While there have been no sleep loss/fatigue studies conducted under high-G, there has been a G-layoff study conducted. The issue was the effect of G-layoff on tolerance, not performance. No medical risks were identified from having subjects exposed to +9 G_z after 2 and 4 weeks of G-layoff; however, a four week layoff was found to reduce G endurance from 220 to 163 seconds during an alternating 5 to 9 G profile [26].

Physiological changes under high-G include primarily a redistribution of the blood supply to various organs [27]. The most commonly encountered acceleration ($+G_z$) causes a shift of blood from the head to lower parts of the body. Because of this blood shift, loss of vision and even loss of consciousness may result. These effects have been well studied and have been shown to be both without permanent effects and spontaneously reversible when the + G_z force is reduced [2]. Centrifuge subjects are instructed during training in the proper straining maneuvers to help prevent these effects of high-G stress. In addition, all subjects wear anti-G suits during high-G exposure. High-G stress can affect the heart and lungs as well. Microscopic sacs in the lung may collapse, a condition known as atelectasis, which may be asymptomatic or result in a sensation of chest fullness or congestion. Effects upon the heart include irregularities of rhythm, most of which are self-limiting and resolve with cessation of high-G stress. Small breaks in the skin capillaries (petechial hemorrhage, or "G measles") and/or small bruises occasionally appear on the arms, legs, trunk, or buttocks, but these are normally considered to be harmless. Because of the anti-G straining maneuver and inflation of the anti-G protective equipment, subjects will experience increases in both intra-abdominal and intra-thoracic pressure. This increased pressure may cause and/or worsen hernias, hemorrhoids, varicose veins, varicocele, and thrombophlebitis. Fracture/dislocation of skeletal bone is theoretically possible under high-G stress, but has not been observed here or at other centrifuge facilities.

The effects of acceleration on a pregnant woman are virtually unknown, and the risks of injury to the woman cannot be ignored [28]. In addition, the effects of acceleration on a developing fetus are little known and the potential for fetal injury, malformation, or even death may be significant [29]. For these reasons, pregnancy precluded participation in this acceleration research.

PURPOSE OF PRESENT WORK

The purpose of the research described herein was to investigate mission performance in the high-G environment after periods of sleeplessness and after periods of layoff with enough female subjects to make inferences to the general female aviator population.

APPROACH

This research was conducted on a ground-based human centrifuge, the Dynamic Environment Simulator (DES), located at Wright-Patterson AFB, OH and shown in Figure 1. The DES is a unique research facility which couples simulated high-G with a flight simulator capability that provides the means to measure psychophysiological, behavioral, and subjective reports of mission performance, workload, and situational awareness [30].

BODY

METHODS

Subjects, Qualification and Training

Out of nearly 70 individuals that applied at Wright Patterson AFB, over half could not pass the medical screening criteria and half of the remaining attritted out of the subject pool prior to useful data collection. Sixteen active duty non-rated Air Force subjects (8 men, 8 women) were retained and passed the rigorous medical screening procedures including spinal and cranial radiographs, blood analysis, and neurological examination. All were briefed on the study, signed an informed consent, and received suit, helmet, and mask fitting and anti-G straining maneuver training. Coincident with an eight visit indoctrination series that introduced motion sickness coping strategies, anti-G straining techniques, positive pressure breathing, and DES safety procedures, subjects completed 8 to 20 classes in the static simulator learning to fly and complete the multiple tasks. Then each subject underwent a minimum of three days of training that blended high G endurance with the flight simulation.

After each subject demonstrated their ability to safely and reliably fly the closed loop simulation, they were assigned to the experiment. The schedule was mapped out for weekly runs to include a minimum of 3 blend days (blending G tolerance with flight simulation) or until their performance was consistent (SEM of tracking score < 1000 ft, approximately, as scheduling allowed). Assignment to the experimental design was balanced for order, gender, and skill level.

Protective Equipment

COMBAT EDGE (Combined Advanced Technolgy Enhanced Design G Ensemble) was selected as the protective equipment because that is what is now required in the F-15 and F-16. Ten women in the USAF currently fly the F-15 and F-16 aircraft.

Protective equipment was customized to accommodate both men and women. In operational scenarios these types of modifications are common practice [31]. Five women and six men reduced the height of their anti-G suit abdominal bladders. Arm pain has been a by-product of PBG protetion, especially in the centrifuge, thus four women and six men elected to wrap their arms to avoid arm pain. Due to the oxygen sensing transducers on the forehead, some subjects required larger helmets than normal and the high-style bayonets had to be used to get a good mask fit.

Flight Task and Metrics

The Dynamic Environment Simulator was enhanced with a wide field-of-view visual display for presentation of a closed-loop flight task where subjects trained to control the

onset/offset of high-G according to the requirements of the flight. A computer generated, projected, instrument panel was installed and controlled by specialized software. The subjects were tasked to perform the following:

- Maintain controlled flight
- Follow lead, maintain 3000 ft range (tail chase)
- Discriminate call-sign and correctly respond
- Report any 5000 ft altitude breaks
- Upon klaxon, find and evade missile (Attitude, Chaff, Direction, max G)

Metrics for both effects of fatigue and G-layoff included the measurement of closed-loop flight performance, overall + G_z dose, and reaction times/error rates to secondary tasks related to the mission. Performance metrics were measured for two initial 1G runs (normal 1G environment) followed by four real G runs (DES arm active) with three minute rest periods between each run. Each 3 minute engagement was designed to emulate an air-to-air targeting sortie. The target profile was randomly selected from a library of profiles prerecorded to contain similar G dose and maneuvers of equivalent difficulty. Metrics recorded for the primary task included mean RMS error from the target and G dose (both as an integral, and as a distribution).

The multifaceted task included not only pursuit tracking, but speech discrimination, choice response, altitude reporting, and missile evasion. The missile was always the final portion of the sortie and required situational awareness, spatial and cognitive decision making, and high G tolerance.

HUD Task

Throughout the flight task, the subject reported (via a switch on the throttle) every time that the engagement altitude floor was violated. Profiles were constructed so as to break the floor approximately every 30 seconds during each sortie. Data recorded were the number of breaks occurring, the number to which the subject responded to within 10 seconds, and the average reaction time of responses.

Head Down Task

The head down task was coupled with the flight task. It consisted of the radar warning receiver display that told the subject which direction the target aircraft was when it was no longer visible on the forward visual scene and the direction from which the missile had been launched. Missile metrics recorded included reaction time to trigger chaff button, peak G pulled, and successful solution (kept missile abeam long enough to evade).

Communications Task

The profile software included computer recordings of three different call signs and instructions. These occurred every five seconds. If the subject recognized his/her call-sign, he/she responded by following the instructions indicating which of three buttons on the flight stick to engage. Example: "Bird 2, Squawk Charlie", if the subject was Bird 2 on that day, he/she should push the right-most (Charlie) button. Metrics recorded included number of calls to the subject, number correctly responded to, and average reaction time from start of instruction word to button push (must be correct button to count).

Subjective Workload Measures

In addition to the various quantitative measures of performance, subjective measures of workload and performance were also obtained using both a computerized version of the six dimensional NASA-TLX and a locally developed paper questionnaire.

Physiologic Measurements

A Nellcor N-200 pulse oximeter was used to measure arterial oxygen saturation at head level via a RS-10 oxisensor. These data were collected 15 seconds prior to, during Gz, and for 30 seconds post G exposure.

A Somanetics INVOS 3100 cerebral oximeter measured transcranial regional cerebral oxygen saturation using a near infrared Somasensor. Both the N-200 and the INVOS 3100 devices have undergone extensive clinical validation at 1Gz, however, neither unit has undergone validation at G >1.

Experimental Procedures - Fatigue

During nights in the sleepless condition, subjects reported to the DES facility at 10 PM and were supervised throughout the night. There were no specific activities required, as long as they stayed awake. Caffeine intake was restricted to only what they would normally consume (e.g. 1 cup in AM). No more. Closed-loop performance was measured the following morning at 7 or 8 AM. Subjects were then driven to their homes for rest.

Experimental Procedures - G-Layoff

Subjects were divided into four groups of equal number: 1) males with G-layoff of two weeks, 2) females with G-layoff of two weeks, 3) males with G-layoff of four weeks, and 4) females with G-layoff of four weeks. After the prescribed layoff period, subjects once again underwent the standardized high-G sortie and performance metrics were collected. Due to both attrition (active duty transfers to other stations) and reduced access to the DES the final subject counts completing the layoff portion of the study were 7 men (4 on two-week layoff, 3 on four-week layoff) and 4 women (2 on two-week layoff, 2 on four-week layoff).

Data Analysis

Performance, physiologic, and workload data were tabulated in a large Excel database with each observation identified by all treatment conditions. Combined score was produced using the weighted sum as follows:

Combined score =
  60% of normalized RMS
+ 5% of percent calls correct
+ 5% of normalized call RT
+ 5% of percent breaks reported
+ 5% of normalized break RT
<u>+ 20</u> (if missile evaded)
  100 % total

Analysis on score was also performed on the continuous tasks separate from the binary task of missile survival. Several significant response metrics were also analyzed individually.

A single factor, 4-level analysis was performed to examine run order effect. Data were then examined using a combination of:

- two-way ANOVA, within gender, blocked by subject
- three-way ANOVA with subject averages
- the Chi-squared test for binomial data
- linear regression

Results were considered statistically significant with a p value of less than 0.05. Power of a test was considered acceptable if greater than 0.8.

RESULTS

Run Order Effect

Although a significant difference in the variance between no G stress and G stress runs was found, there was no systematic increase or decrease in scores across the runs with G stress. One might expect an increase due to practice or a decrease due to fatigue. These either canceled one another or did not occur. Some other response variables were also tested for run order effect with no meaningful findings. Thus in the following analysis, data were regarded as four repetitions within the treatment conditions.

Effect of Fatigue on Performance

Figure 2 shows the results of just the primary task, pursuit tracking, shown here in inverse log units such that a higher bar represents better range tracking. Neither male nor female tracking was significantly affected by sleep status.

Individual task analysis showed two significant components affected by sleep status:

- call-sign reaction time was longer by 33% in the sleepless condition (3.1 vs 2.4 sec)
- missile survival was significantly less likely in the sleepless condition (50% survival sleepless vs 75% survival rested)

Percent correct of either the call-sign task or the altitude breaks was unaffected by sleep status. These differences were not sufficient to affect the overall score. Figure 3 shows the results in the combined score. Neither males nor females were affected by sleep status, overall. Using the mean square error attributed to the sleep factor, the degrees of freedom of the factor, the degrees of freedom of the sample space, and the pooled variance, the power of the test was found to be 0.92.

The NASA Total Workload Index (TLX) means are shown in Figure 4. Statistically significant differences are found in a few of the dimensions; perceived effort and physical demand are higher when sleepless while perceived performance is lower when sleepless. Somewhat unexpectely, reported frustration level was lower when sleepless. Overall, though, the weighted workload was not different in either sleep condition or between genders.

Effect of Layoff on Performance

The single factor (baseline vs laid-off) ANOVA on each of the four conditions (female two-week, female four-week, male two-week, and male four-week) showed no statistically significant differences in RMS tracking, call-sign reaction time, G dose, time > 8 G, or combined score. A slight tendency appeared for the males to have a drop in score after 4 weeks of layoff. The lack of significant results is likely due to the small N-size, since the power of most of the tests was less than 0.4.

Effect of Gender on Performance

The three-way ANOVA also revealed that the female's average RMS range from the lead aircraft was worse than that of the males. The gender difference is significant only in the dynamic case. That is, in a 1G flight simulator situation, women and men's tracking was equivalent. However, when the G forces are added, the women could not maintain tracking range as well as the men. These results for tracking are shown in Figure 5. Similar results appeared in overall score and are shown in Figure 6. Individual task analysis showed several of the secondary metrics were affected by 1G versus real G conditions. Call reaction time was nearly doubled, percent of altitude breaks reported was down by 20% and missile survival was reduced by 8%. Overall there was a highly significant effect of gender, in the G stress condition, on combined score. This effect was not significant during 1G simulation.

Self Induced G Dose

Figure 7 shows the results of the three-way ANOVA on G dose, that is the integral under the profile curve but above 3 G. The 3 G lower limit is necessary due to the non-linear relationship of the aero-model and the DES response below 3 G. These results show, again, that sleep status had no effect on the amount of G that the subjects commanded. In the case of the male data, 1G simulation versus simulation with G stress did not influence the commanded G. However, the women commanded significantly higher G loads when the load was not real (in 1 G simulation). When the G stress was added, the women endured a G dose equivalent to men.

Figure 8 shows the average number of seconds spent in each G range by the target aircraft, by the females, and by the males. This is the average for only the real G case, not including the 1G simulation. Previously described results showed no significant difference in overall G dose during real G between genders. Closer examination using the number of seconds in each G range as a response variable, showed that there was a significant difference between genders in the time spent above 8 G. Females spent an average of 15 seconds in that range, while males spent an average of 10 seconds.

Having found a significant difference between genders in both performance and time-at-high-G, one would wonder what is the relationship between these variables. Perhaps greater time at high G would cause a reduction in ability to perform the tasks, thus reducing score. Or perhaps more time at high G was necessary to get a high score. In fact, as Figure 9 shows, there is no obvious relationship between these two response variables. Apparently there are a wide range of successful strategies allowing some people to obtain good scores with lower G dose as highlighted in the box. These are the people who truly optimized the task.

Observed Incidents

In addition, the following incidents were noted throughout all of the indoctrination, blend, data, and layoff data days thus far:

Among women:

- 1 case of chest pain (medical exam showed no cardiac or pulmonary source)
- 1 case of severe neck pain (resolved with time)
- 2 cases of partial central light loss
- 2 cases of complete central light loss (after 2 week layoff)
- 4 cases of severe motion sickness

Among men:

- 2 cases of moderate motion sickness

No cases of simulator after-effects were reported.

Effect of G on Physiologic Measurements

Regional cerebral oxygen saturation values both in the sleepless and rested conditions, showed that rSO2 values decreased significantly less in the female population during the +Gz exposures when compared to their male counterparts. This was also true for the post G rSO2 data as well.

Brain oxygen saturation dropped for both genders throughout each sortie and the minimum value was typically (almost always) at the end of the profile. Examination of this minimum as a function of time spent at G for each gender is shown in Figure 10. Both linear regressions were significant with the slope being approximately twice as steep for the men.

The physiological measurements of peak pulse rate, 30 second post G pulse rate, minimum arterial oxygen saturation, and 30 second post G oxygen saturation showed some statistically significant changes after layoff.. Table 1 summarizes the effect of layoff on each of these variables. The most striking result is the considerably lower peak pulse rates for both genders after 4 weeks of lay-off.

		Peak Pulse Rate	Post-G Pulse Rate	Min SaO2 (%)	Post SaO2 (%)	Min rSO2 (%)	Post rSO2 (%)
2-Week Layoff							
Male	Current	155.	144	**88.7**	94.2	52.0	53.0
	Layoff	148	140	**90.5**	94.8	53.0	52.6
Female	Current	156	**144**	91.3	**94.4**	59.0	60.1
	Layoff	161	**126**	93.0	**96.7**	57.9	61.4
4-Week Layoff							
Male	Current	**153**	119	92.8	97.1	56.0	56.9
	Layoff	**123**	127	91.2	95.4	54.5	60.1
Female	Current	**144**	137	87.7	92.7	57.7	63.7
	Layoff	**123**	124	91.8	91.4	55.2	49.4

Table 1. Physiological Measures Compared Between Current and Laid-Off Conditions. Bold indicates statistically significanct difference at $p \leq 0.05$

DISCUSSION

The lack of effect on overall performance of 24 hours of sleeplessness is the primary result of the study, however further analysis and results indicated several significant findings with respect to gender differences in performance under high G and the value of performance research conducted in conjunction with physiological tolerance measures.

The poorer tracking by the females resulted in a their trying harder to catch-up with the target. In this scenario, this is accomplished primarily by turning tighter than the target. Women were trying to catch-up in the 1 G simulation, turning tighter and pulling more G. But when G loads were real, the women endured loads similar to that of the men - and their tracking scores suffered.

Regional cerebral oxygen saturation values both in the sleepless and rested conditions, showed that rSO2 values decreased significantly less in the female population during the +Gz exposures when compared to their male counterparts. This was also true for the post G rSO2 data as well. One possible explanation for this difference may be related to the shorter hydrostatic column height of women compared to men. This slight hydrostatic advantage may provide for better cerebral cortex perfusion in women during G. Another explanation may be that women may be more physiologically resistant to the stagnant hypoxic effects of G. A review of work conducted by Arnold et al. [32], using the same cerebral oximeter to study the effects of graded hypoxia on cerebral tissue in a mixed gas experiment simulating altitudes of 13,000, 15,000 and 17,000 ft, showed no differences in women's regional cerebral oxygen saturation compared to the male population. Unfortunately the female population was small (n=3).

In mixed gas studies and hypobaric studies, the literature shows that decreasing oxygen saturation is correlated with cognitive decrements. But plotting saturation against the combined score did not support this, primarily because saturation was maintained above 80%, the level at which performance decrements can typically be seen. This welcomed result supports the claim that COMBAT EDGE does and excellent job of helping pilots maintain eye level blood perfusion during high G maneuvering.

One might also expect a negative correlation between arterial saturation and time-at-high-G. Our data did not reflect this. Those who spent the extra time at the higher G were still able to keep oxygen saturation at levels comparable to those with less time at high G. Again, this speaks well for the level of protection provided by COMBAT EDGE.

The multidimensionality of the G dose, performance, and physiology data make it difficult to visualize interactions. Having already found a gender effect in time-at-high-G, cerebral oxygen content, and score, a database to map out the performance surface in the space of these three affected variables was produced and shown in Figure 11. There are insufficient data across this space to reach any scientific conclusions because these are all response variables, not controllable inputs. Nevertheless, the surfaces suggest that the men had a stronger optimum point of performance, at which they used just the right amount of G to get the best score. High G loads and reduced oxygen are associated with poorer scores. The women, on the other hand, did not manifest an optimum point. Their scores were poorer, overall, regardless of their possibly better brain oxygen status. Females' tendency to spend more time at higher G was associated with lower scores rather than higher.

The lack of significant change in performance after a two or four week layoff is likely due to the small N-size, since the power of most of the tests was less than 0.4. The extended time-

frame of this study and individual schedules of volunteer subjects makes it difficult to control, however subjective reports, anecdotal incidents, and preliminary adaptation results indicate that beyond two weeks of layoff workload is increased, and beyond four weeks layoff performance is decreased. In addition, this study showed a reduction in peak heart rate after a 4 week lay-off, suggesting that some physiological deconditioning has occurred.

Salient Points

The women in this study were willing to pull the G, as much as men, even spending significantly more time in the highest G ranges. And the women may have maintained brain oxygen content better than the men.

Thus, pure G-tolerance or physiological measures would have concluded that the females were superior at coping with high G, compared to the males. Actually, performance metrics reveal that the women could not perform the cognitive task of an air-to-air sortie at high G as well as the men.

Performance metrics must include situational awareness and complex decision making to be sufficiently sensitive to operational issues such as fatigue or layoff. Within this simulated sortie, the missile evasion task showed a significant sensitivity to fatigue.

CONCLUSIONS

Twenty four hours of sleeplessness had little or no effect on the basic psychometrics of pursuit tracking combined with discrimination-choice-reaction-time tasks in either gender. However, a complex task involving situational awareness of attitude, altitude, airspeed, and heading, both of self and of the enemy, was twice as likely to fail in the sleepless condition.

In the 1G situation, women commanded significantly higher G loads than men, yet did not accomplish better scores. But once G forces were added, they pulled G doses comparable to the men. Although, women still spent an average of 15 seconds above 8 G while men spent only 10.

Women dropped their commanded G when the G became real. Coupled with this drop in load, was a significant drop in tracking performance and combined score. The women apparently could not optimize the tracking task as well as the men when G was in the loop. Women also reprted significanlty more physiologic incidences to the flight surgeon as as result of G exposure.

This research found no "show stoppers" in the evaluation of men and women performing complex cognitive tasks in the high G environment. Although none of the subjects were pilots, they all learned to fly an F-16 simulation closed loop on a human centrifuge and were able to command as much G as the F-16. Nothing was found that suggests that women should not fly high performance aircraft.

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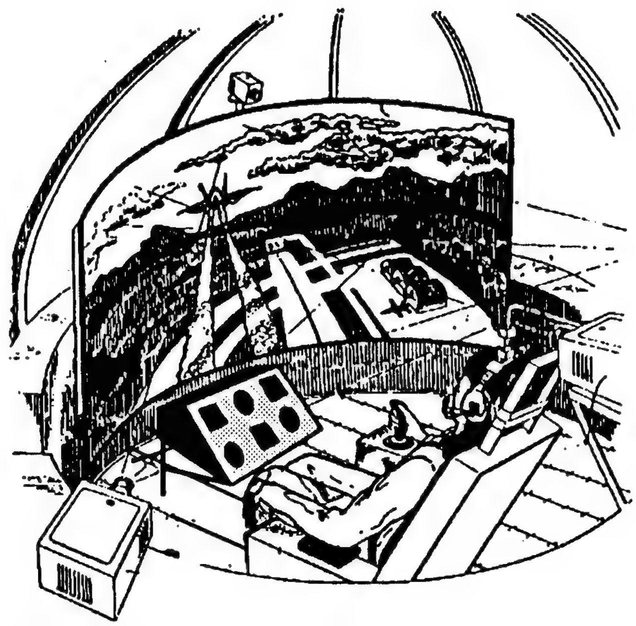

Figure 1. Dynamic Environment Simulator Cab Configuration.

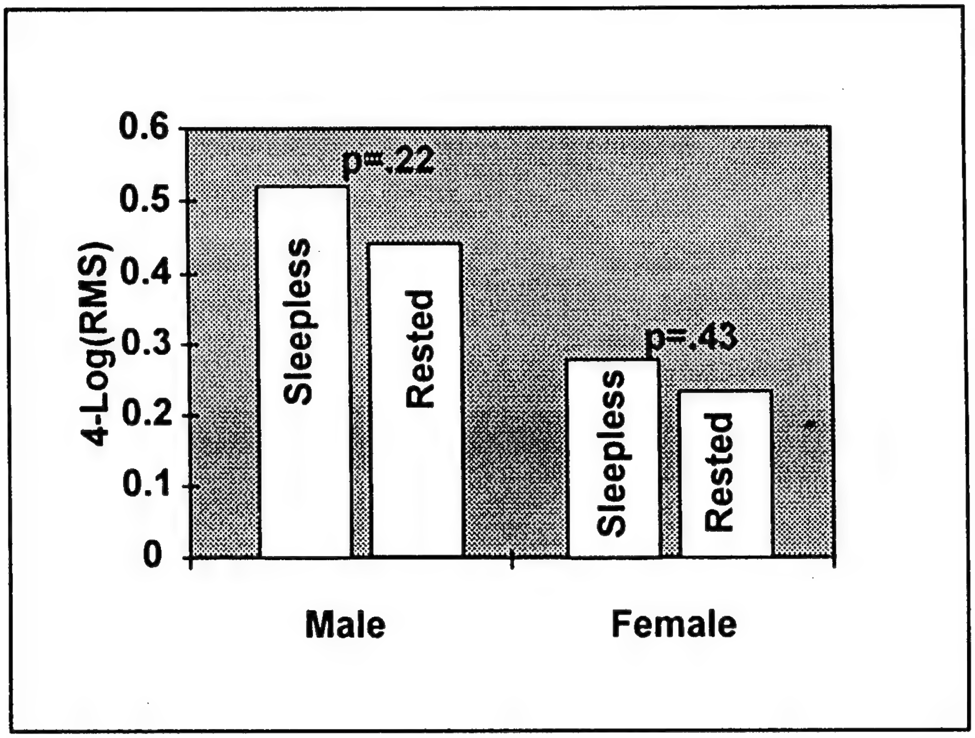

Figure 2. No Effect of Sleeplessness on Tracking

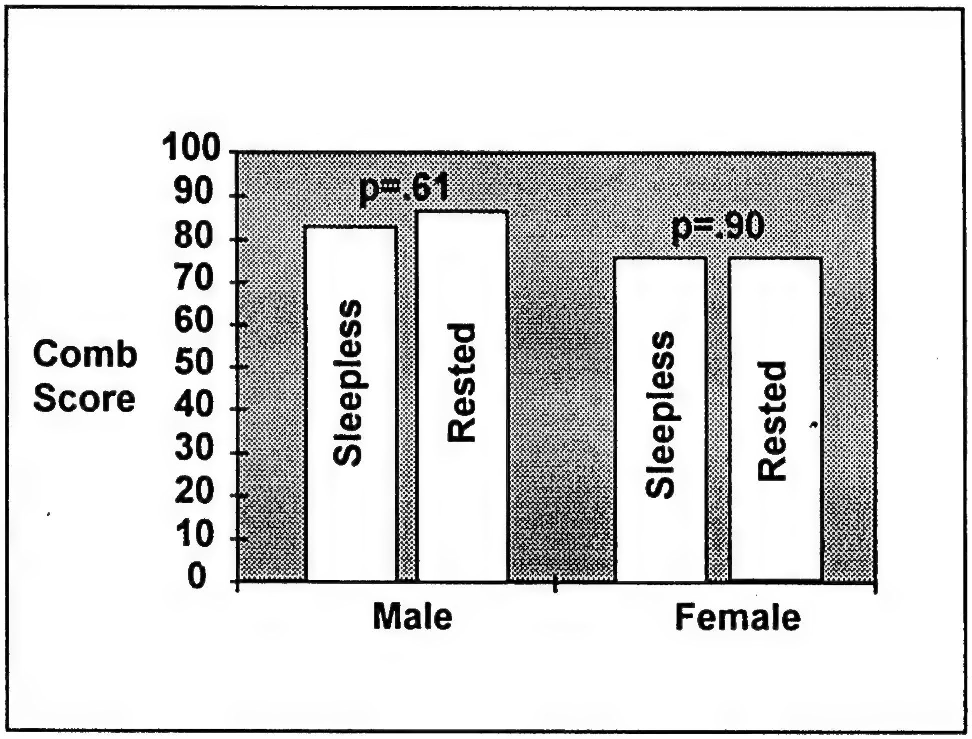

Figure 3. No Effect of Sleeplessness on Score

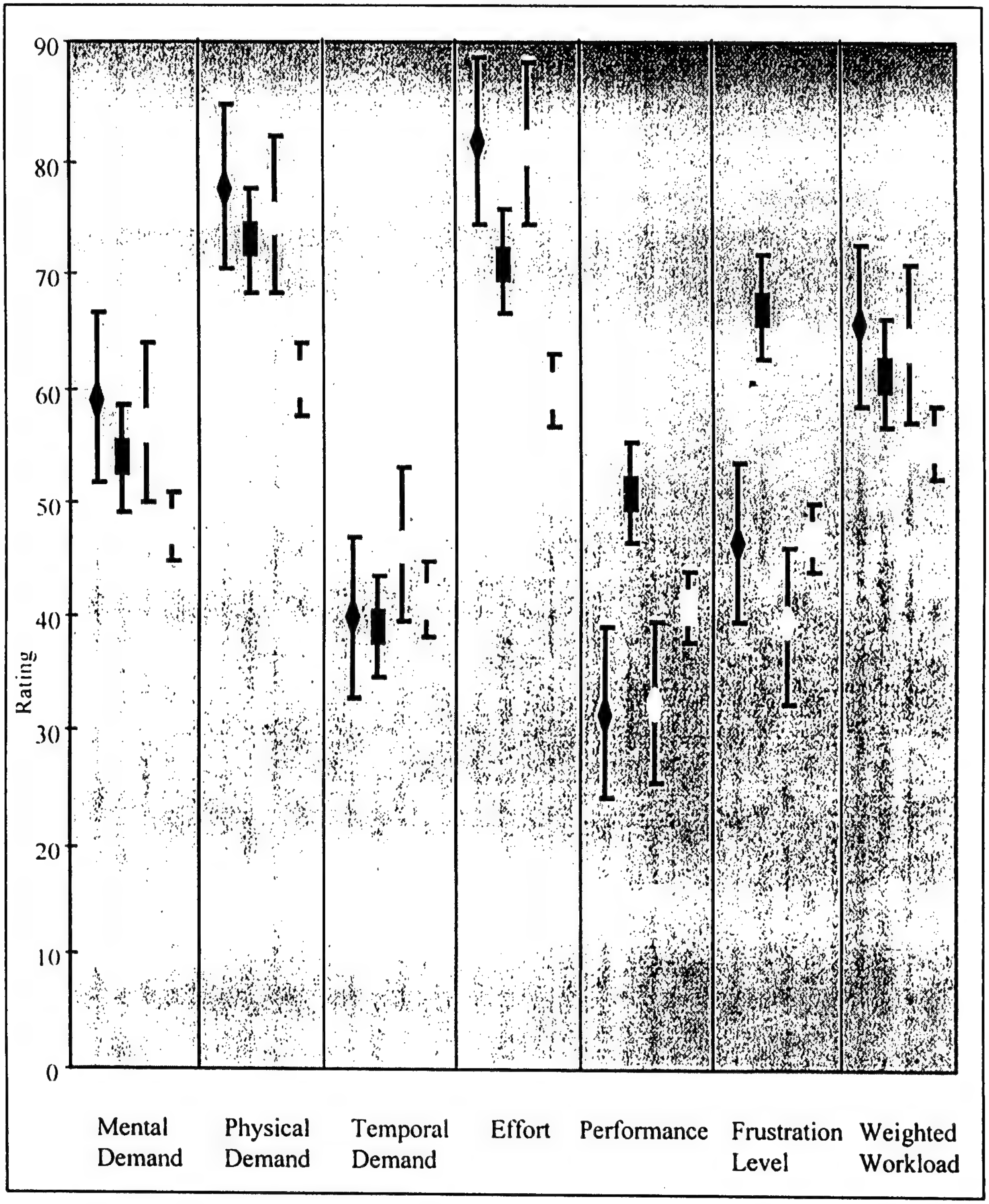

Figure 4. NASA Total Workload Index (TLX) Scores.

Females: Sleepless Females: Rested Males: Sleepless Males: Rested

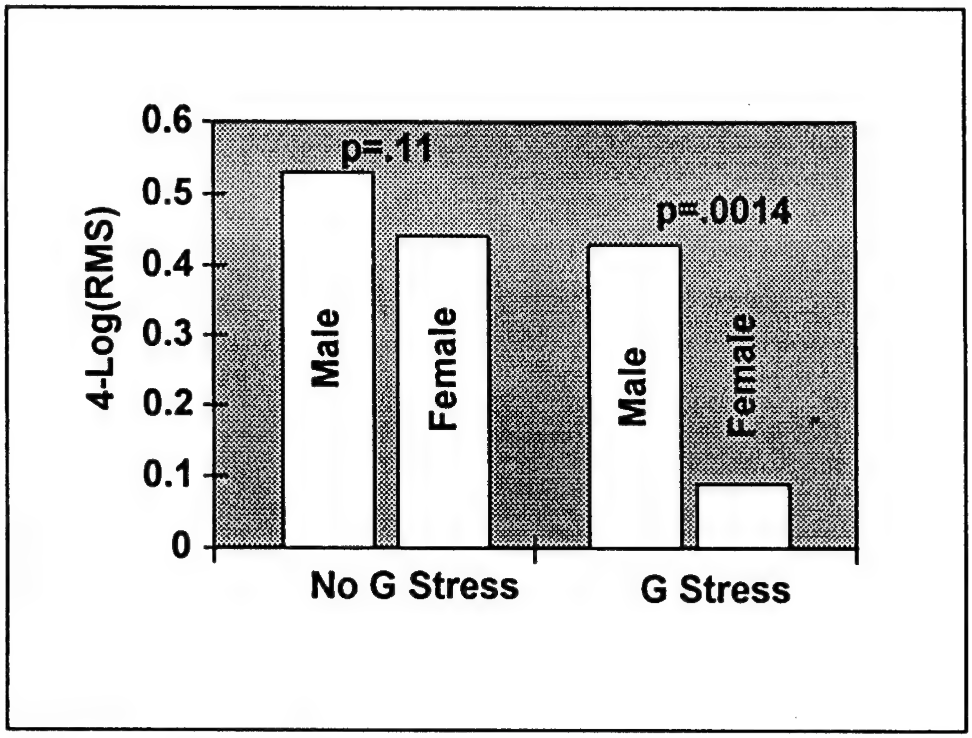

Figure 5. Effect of Dynamics on Female Tracking

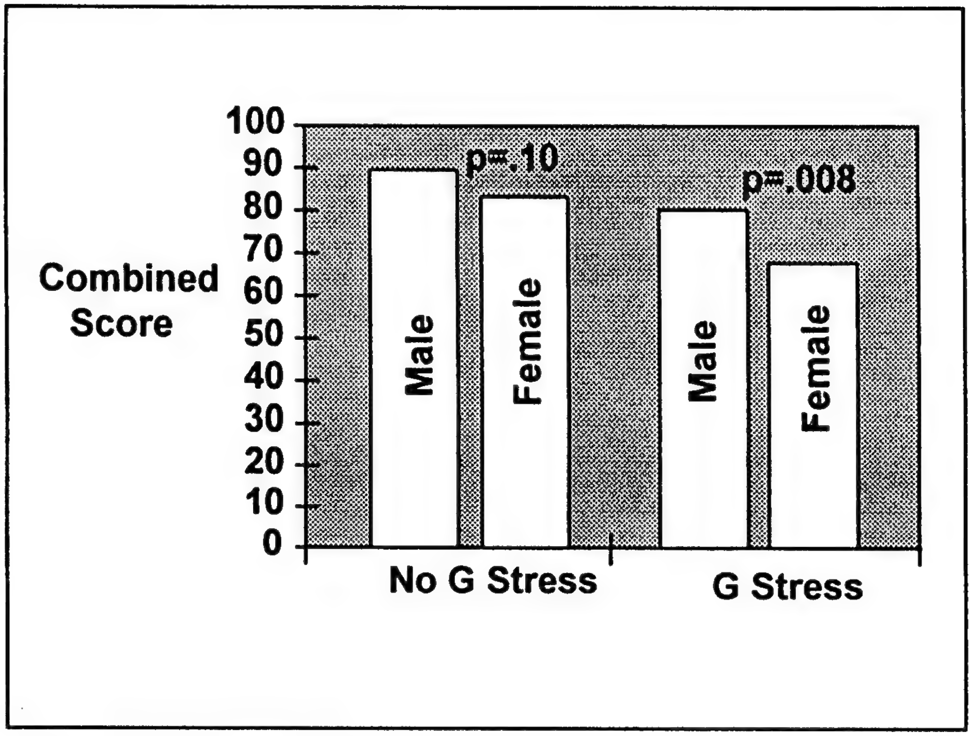

Figure 6. Effect of Dynamics on Female Score

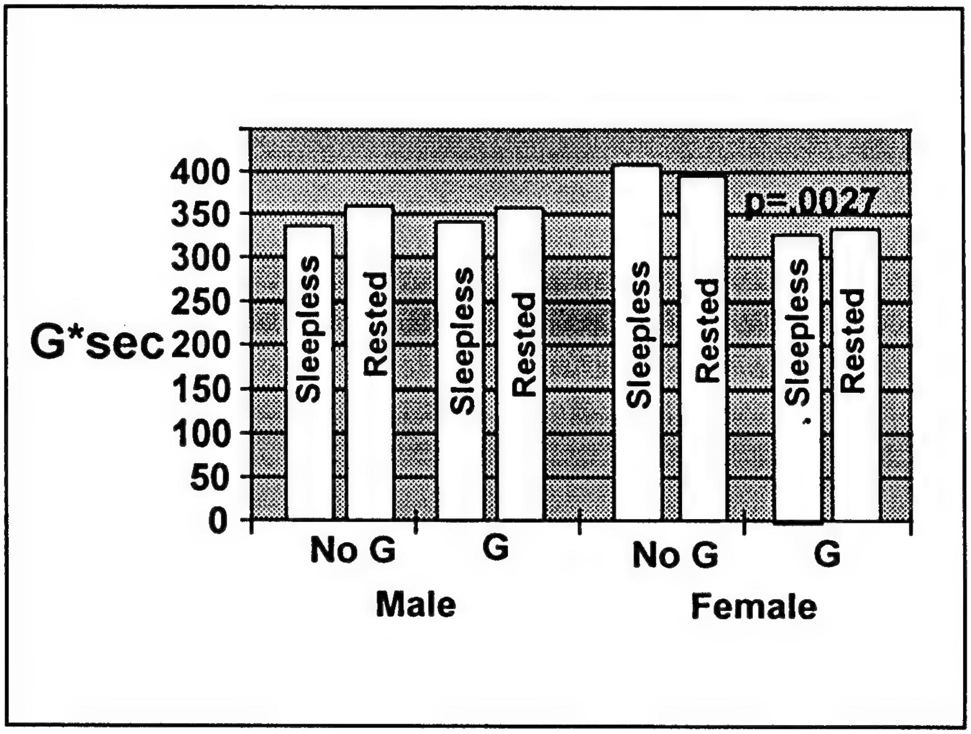

Figure 7. Self Induced G Dose

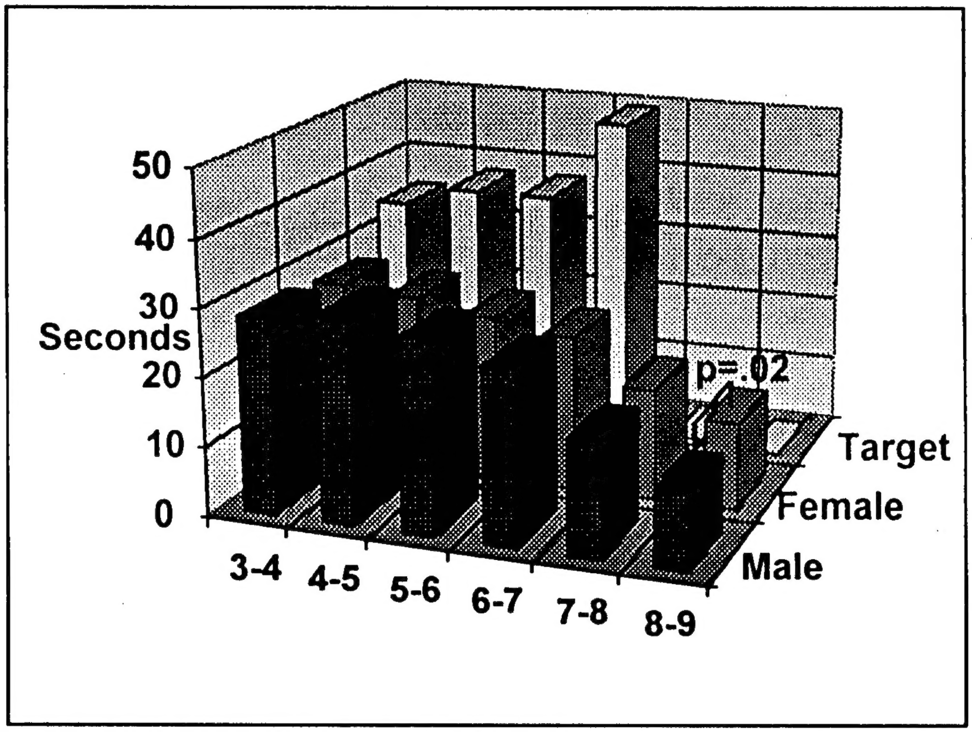

Figure 8. G Distribution

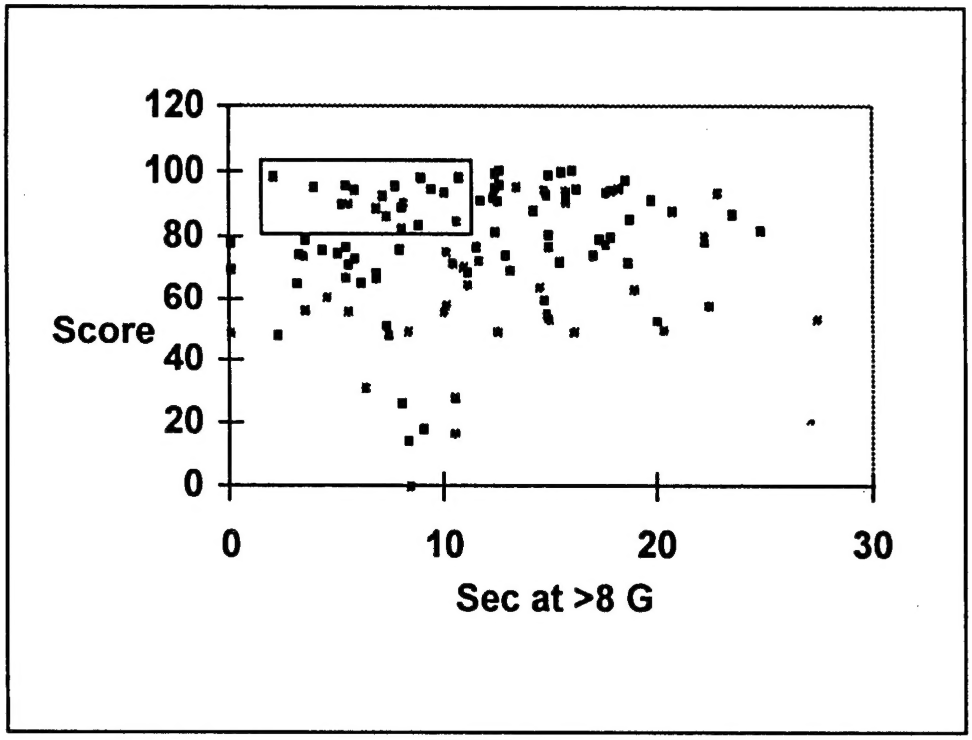

Figure 9. Performance vs Time at High G

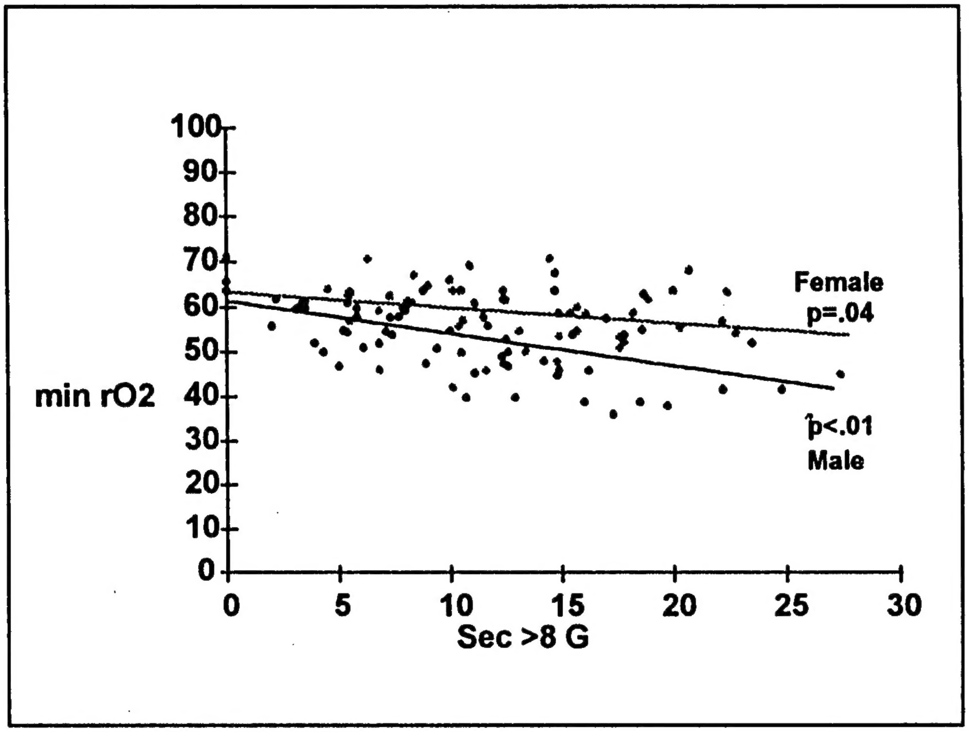

Figure 10. Cerebral Oxygen vs Time at High G.

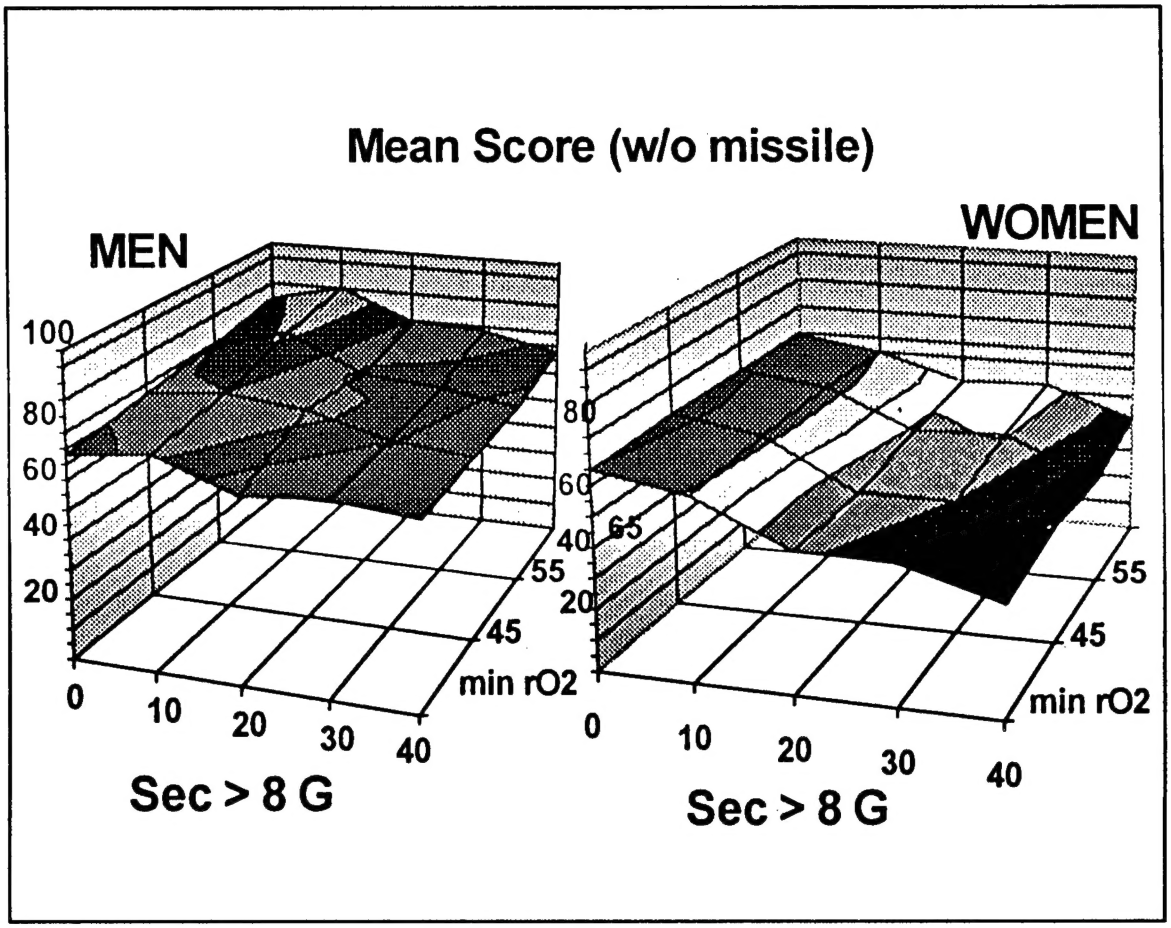

Figure 11. Performance Surface.